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THE PROBLEMS OF POTATO BREEDING

S. M. Bukasov

U. S. S. R. Institute of Plant Industry, Leningrad, Russia

Our principal problems and final aim in studying the potato as in studying any other crop plant is to improve its yield and quality. Yield, like any other genetic character, is the end result of the interaction of many factors within the plant itself, a living organism and factors of environment, the latter controlled to some extent by the agricultural activities of man.

During the early cultivation of the potato and during two centuries of its cultivation in Europe the emphasis was placed on cultural practices and uses. However, in the twentieth century, especially in the last decade, a change has taken place in the direction of studying the potato as a living organism. The biology, physiology and biochemistry, disease resistance, breeding and genetics of the potato are now being studied and it is these branches of science that have engaged the interests of the Soviet workers in recent years. Formerly most of the work was done with the varieties of Europe and North America with little consideration given to the home of the potato crop, South America. In recent years, South America has been given more consideration and exploring expeditions sent to that country by the Soviet Union, the United States and Germany have brought back hundreds of varieties and species, some of which may have been grown by the Indians for many hundreds of years. For the most part this paper deals with the diversity of material secured by these expeditions.

What has induced the workers in the Soviet Union to study more intensively the potato as a living organism and to attempt to improve its yield and quality? The yield data in the experimental fields of the net of U. S. S. R. state variety testing stations showed the maximum yields of the best varieties to be approximately three hundred bushels to the acre. Much higher yields have been obtained by the Germans

and in the United States of America a number of yields have been reported exceeding one thousand bushels to each acre. A number of yields of single plants in Russia showed the possibilities of increasing the average yields for the country by the production of varieties adapted to the various potato growing districts and by the use of improved cultural practices. Single plants in Shuntuk yielded 6.6 lbs. to the hill, in Pamir 7.7 and one plant grown from seeds under the usual conditions of a truck garden near Leningrad yielded 8.8 pounds to each hill.

Breeding of the Potato

The principal factors responsible for reduction of yields are diseases, frost and drought. The annual loss in the potato crop through diseases is twenty to thirty per cent with late blight (*Phytophthora infestans*) being responsible for from one-third to one-half of the total loss. The virus diseases are also destructive. According to Spangenberg, the former Kiev district lost in 1928 about 9 million bushels of potatoes through virus diseases. In the United States the losses from virus diseases in 1926 and 1927 ranged from approximately 8 million to more than 14 million bushels. Even in England where the acreage under potatoes constitutes but 1.8 per cent of the world's acreage, the annual loss from virus diseases is more than 66 thousand bushels, and the losses from late blight 50 thousand bushels.

In order to obtain a wider range of material for breeding for resistance to the various diseases, to drought and to frost the Institute of Plant Industry sent the first expedition to South America in 1925 with S. M. Bukasov at its head. This expedition was continued by S. V. Jusepczuk and terminated in 1932 by Acad. N. I. Vavilov and E. Kesselbrenner, the latter two exploring in Mexico as well as South America. The expeditions collected in South America a large amount of material of wild and cultivated varieties. A study of this material in comparison with the world assortment of commercial varieties has shown a great diversity of types. The commercial varieties of the principal potato producing countries of the world are closely related to the Chilean potatoes forming the so-called species *Solanum tuberosum*. All other native varieties belong to a geographically isolated group grown only in the high mountainous regions of South America. Taxonomically this Andean group falls into eighteen well differentiated species having their individual areas. The concept of the cultivated potato must be extended to include not only the commercial varieties of potatoes but to embrace all the species and

varieties known at present. Cytological studies have shown chromosome numbers ranging from diploids ($2n=24$) to hexaploids in the wild species and from diploids to pentaploids in the cultivated forms. The reduction division of the triploids and pentaploids is very irregular indicating that these species are possibly of hybrid origin.

The study of the phylogenetic relation between species as shown by interspecific hybrids indicates that within the section *Tuberanum* of the genus *Solanum* there are taxonomic groups rarely crossing with each other or producing no inter-group hybrids at all. Further it has been established that in the absence of male sterility, crosses between species of the same chromosome group are successful. The crossability of species and the sterility of hybrids are not always an index of the genetic relation of the species used in making the crosses. Sterility is sometimes observed in hybrids between a variety of the same species such as the majority of Chilean tuberosum and many commercial varieties. The anatomical characters distinguishing the potato species have been established by Chicovani, Nassonov, Jager and Yakovlev, according to the degree of development of the palisade and mechanical tissues, size and number of stomata, shape and size of the hairs, as well as the starch grains.

Some species are characterized by immunity from various diseases. Immunity from *Phytophthora* has been found in some of the Mexican wild potatoes. The *Pinnatisecta* of Argentine and Uruguay are resistant to the Colorado beetle.

Physiologically the species differ in their vegetative period and the resting period of the tubers, frost hardiness, the temperature required for sprouting of the tubers and of flowering, their transpiration coefficient and the photoperiodic response of flowering and tuber formation. *Tuberosum* yields an economically profitable crop both beyond the polar circle under continuous daylight and near the equator under a 12-hour day. The optimum day length is thereby one exceeding thirteen hours. Tuber formation in *tuberosum* responds readily to day length. Photoperiodic plasticity is a purely specific character. The fact that near relatives of *tuberosum*, originating at the same altitudes and even in the same localities, fail to form tubers under the long day of Leningrad is a character more surely distinguishing them as species from *tuberosum* than morphological characters. The optimum for tuber formation in all other wild and Andean species is a short day—less than thirteen hours. In some cultivated species when grown under an eighteen-hour day the yield is only slightly reduced, constituting 50-75 per cent of the yield obtained under a

twelve-hour day. Such species are *S. Rybinii sp. coll., S. phureja, S. cuencanum* and a few *andigenum* (*tocanum* and others). In the rest of Andean species and especially in wild potatoes, when transferred to long days, the yield is considerably reduced and may even completely fail.

The phenomenon discussed above is of great interest to us as the bulk of species valuable for the breeding purposes are short-day plants, and it seemed problematic whether the utilization of such species in potato breeding were possible at all. The wider circles and more superficial plant breeders assumed a skeptic attitude toward these species. An experiment, however, has refuted this opinion and has proved the possibility of utilizing such material in plant breeding. It has proved moreover that the phenotypically negative photoperiodic response, implying short-day habit of life, may conceal high genotypical productivity.

Under our conditions short-day habit of life involved late tuber formation, a low starch content and extremely vigorous root characters evidently conditioned in Andean species by a great number of intermediate and dominant genes (Schick).

With respect to the productivity of *andigenum* the last tests have given us several pleasant surprises. In the first years I was too rash in advancing the supposition that *andigenum* being late, with a long period for accumulation, must produce high yielders. Unfortunately several attempts at cultivating a collection of *andigenum* in our south—Ukraine, Polessye, Odessa and the Kuban region—did not confirm this supposition.

Only in 1934, sometimes under quite unexpected conditions, valuable results were obtained. Especially interesting were the figures obtained in the Pamir where *andigenum* yielded more than 7½ pounds to each plant surpassing all commercial varieties. This indicates the necessity of new tests of the Andean species under more suitable conditions.

The fact that the majority of potato species are short-day plants makes it difficult to determine the genotype of their earliness in the economical sense, i. e. early tuber formation, as under our conditions all of them are late. Even in the early *phureja* which, under shortened days began like *tuberosum* to form tubers early (on the 24th day according to Rasumov) the growth of the tubers was considerably less than in *tuberosum*. In wild potatoes, as *acaule*, even when grown under short days, tuber formation is extremely late (on the 42-64th day according to Rasumov). The determination of the earliness

of tuber formation was yet more complicated by the fact that shortening of the day alone, without simultaneous study of the temperature, which is of great importance in this matter, could not throw sufficient light on the question.

Earliness was determined in an indirect way by studying the period of rest and the rate of growth of the sprouts, reasoning to some extent by analogies with the behavior of commercial varieties. The specific differences of these potatoes were very considerable on both sides of the range known for commercial varieties. In some geographically, physiologically and taxonomically distant species of the group *S. Rybinii sp. coll., S. cuencanum* and *S. phureja* the tubers have no period of rest and sprout at once after harvest or more exactly, after they have terminated growth which may take place very early if dry weather should prevail. Such species are of great value for the breeding of early varieties and for the solution of the problem of two crops a year, which under the conditions of South America has been realized long ago.

The other cultivated Andean species, among them *S. andigenum* have a longer resting period than the commercial varieties. This is one of the specific characters distinguishing *andigenum* from *tuberosum.*

Finally some of the wild potatoes have an extremely long period of rest. Such are *S. commersionii* of Uraguay, some Andean *Pinnatisecta* of Argentine and especially *S. Vavilovii.* All such species with long rest periods are interesting from the point of view of storing the potato under conditions of the south.

Like photoperiodism the rest period of the tubers depends on the temperature at which sprouting takes place. From the economic standpoint it would be interesting to find species the tubers of which sprout at a lower temperature than those of our varieties. This would permit extra early planting of potatoes.

The first experiment of Rasumov, conducted on a very small scale, has revealed specific differences in the sense of higher temperatures required for sprouting by some *andigenum* (*Caiceda*). Here evidently belong also the already mentioned species *S. commersonii* and *S. vavilovii* characterized by a long resting period. It is possible that these species grow in a warmer climate than the others.

It was a disappointment that the tubers of high mountain species adapted to a most rigorous climate, such as *S. acaule, S. ajanhuiri,* did not sprout at a temperature lower than required by our varieties. It is necesary to conduct experiments on a wider range of material including all commercial varieties. A similar phenomenon has recently

been observed by A. V. Doroshenko on potato seeds. It has been established that in first hardy species of the high mountains (*S. acule, demissum*) the optimum temperature for seed germination is very high: +20°C., just as in the other species and in the commercial varieties.

Both above-mentioned phenomena show that the requirement of a high temperature for the germination of seeds and sprouting of tubers has been inherited from ancestors grown in a warm climate.

This throws new light on the problem of ecologic depression. Indeed, if ecologic depression or "degeneration" of the potato may be explained by our varieties having been transferred from a humid climate to a continental one to which they were not adapted it is necessary to seek the original material for their restoration in regions where the climate is hot. This is of course but a rough outline of a very complex problem requiring deeper analysis.

As regards day length some species begin to flower and continue flowering independently of the length of the day (*S. Rybinii*, the groups *Commersoniana, Longipedicellata, S. maglia*), whereas in the majority of them the amount of flowering markedly decreases under the influence of a short day.

The above-mentioned physiological phenomena in the development of the potato are very important in their relation to potato cultivation. Without mentioning other physiological characters of the potato, such as frost hardiness, drought resistance, immunity, etc., it may be emphasized that the new potato species are of great interest not only to the taxonomist but in an even higher degree to the physiologist, agronomist and plant breeder. They open new horizons and present new problems. The limits of the potato concept have indeed been greatly extended.

It is interesting to note that I, a taxonomist and morphologist, in studying the species problem of the potato, will have to deal very little with external morphological characters but chiefly with genetical, physiological and biochemical characters and it may be necessary to devise a new scheme of classification based on such characters.

Each of the outlined problems—two crops a year, extra early planting, storing qualities—is full of promise. Of still greater importance is the problem of frost hardiness of the potato vine, which has arisen in connection with the new material. The losses from late spring frosts, necessitating late planting of the potato, and from early fall frosts, checking the most vigorous growth of the tubers, are great and universal. It would be erroneous to think that the importance of the problem of frost hardiness is confined to the north.

This problem is no less important for the east and the extreme south. In New Zealand there is a demand for frost resistant potatoes for mountain regions and drained swamps. In the high mountain regions of South America the potato has been grown long since at altitudes of 13,000 feet or more. This is a zone of frequent frosts, where potato species (*S. juzepczukii, S. ajanhuiri, S. curtilobum*) are grown standing temperatures of 21° to 23° F. under a certain humidity of the air. Great humidity of the air decreases frost hardiness and vice versa. In the Pamir we have no frost injuries on the common potato even at 23° F. (Baranov and Perlova).

Wild potatoes such as *S. acaule* ascend still higher almost to 16,000 feet near the line of perpetual snow. They stand temperatures as low as 18° F. But frost hardiness is not confined to high mountain species. Even some subtropical species, for instance *S. commersonii* or *S. millianii* of Argentine, are able to withstand the same frosts as such high mountain species as *S. acaule*.

The works of Rzhavitin have shown that the determination of frost hardiness may be carried out under laboratory conditions. As frost resistance increases there is a corresponding decrease of electro-conductivity of the extract from the vine. This method is rather expedient for the mass estimation of hybrids.* Frost resistance of the potato tubers has not been observed.

Of still greater importance than frost hardiness is drought resistance. Recently Lyssenko directed attention to the fact that in hot regions the productivity of the potato is low. The potato degenerates because in the period of tuber development the weather is dry and hot. This problem may be solved simultaneously following two courses: by summer planting in June as suggested by Lyssenko and by breeding new varieties from appropriate initial material. There are species growing in hot regions. It is necessary to establish the extreme forms with respect to drought both of the air and of the soil.

R. L. Perlova has determined the intensity of transpiration in the potato leaves (in grams per hour from 1 gr. of green weight). This investigation has shown that some cultivated species, and especially wild species excel the commercial varieties. The transpiration coefficient

*The indirect refractometrical method of determining frost hardiness has been used by Rasumov. With the exception of S. acaule belonging to the taxonomically isolated group Acaulia, all species of tuberosum may be arranged according to their frost hardiness in the order of sequence of the decreasing percentage of dry matter in the cell sap (from 12.9% in S. ajanhuiri to 2.9% in S. antipoviczii).

of commercial varieties ranged from 0.215 to 0.990 gr.—that of *S. phureja* was 1671 gr. and *S. Vavilovii* ranged up to 2116 gr. This character is peculiar of the species, not of the habitat, as *S. medians,* occurring in the same localities as *S. Vavilovii* has a coefficient of only 0.932 gr. The above-mentioned figures are of course of greater value for establishing the range of a character as connected with the species than for the direct determination of drought resistance. This is true also with reference to experiments carried on to determine resistance to drought caused by lack of moisture in the soil. The results of the experiment conducted in pots (Chekalova) and the evaluation of drought resistance under field conditions are not easy to interpret. Indeed, it is important to determine the "economical" drought resistance, i. e. the capability of the plant to yield a tuber crop under drought conditions. This "economical" drought resistance may not coincide with the "biological drought resistance" of the plants, which may show itself in greater vigor of the vine and perhaps the yield of seeds, but not of tubers.

The interpretation of experimental results is also complicated by the influence of lower temperatures on tuber formation, which, combined with drought, may induce tuber formation even in short day species, thus obviating the influence of photoperiodism.

In the experiments of Chekalova the best development of the vines and the highest yield of tubers were observed, in the majority of species, at 60 per cent of soil moisture. In commercial varieties receiving 30 per cent of moisture the yield was considerably reduced, as for these varieties the optimum is sometimes about 90 per cent. In species such as *S. mamilliferum, curtilobum, ajanhuiri* and *leptostigma* the reverse was observed. The morphological difference between *S. leptostigma* and *tuberosum* is thereby inconsiderable.

Immunity—Since the introduction of the potato into cultivation much attention has been given to the problem of immunity of the plant to the numerous and destructive diseases repeatedly threatening the very existence of the potato.

Let us recall the epidemic of blight in 1845 causing the famine in Ireland, and the wart disease ruining whole countries. In the struggle against wart disease plant breeding prevailed, and at the present time such countries as England, Germany and Switzerland are growing almost exclusively wart-resistant potatoes. Greater difficulties have been met with in combating blight. The control of the wart was possible within the limits of *S. tuberosum,* but the latter and its Chilian relatives proved powerless against *Phytophthora infestans.* Only the

introduction of new blood, evidently of *andigenum,* gave rise to a new type of varieties with increased resistance (the group Wohltman and others). However, the late maturity of this new type acted as a brake to the work of breeding for resistance and up to the present time it has not been possible to produce an early variety resistant to blight.

An estimation of the whole diversity of potato species has shown that some cultivated *andigenum* are less susceptible to blight and that in them incubation period is longer. Many of the wild potatoes are entirely immune. Immune wild potatoes were first discovered in Mexico, in different taxonomical groups: *Tuberosa* (*S. demissum, semidemissum, Antipoviczii sp. coll., vallis mexici, verrucosum, polyadenium*), *Pinnatisecta* (*S. coyoacanum*), *Bulbocastana.*

In 1934 Sidorov and Yakovleva established the presence of immunity in the Argentinian group *Commersoniana.*

A communication from Salaman (1934) stated that O'Connor had discovered among *andigenum* a form "Aya-papa" immune even to the more virulent biotypes of *Phytophthora infestans.* The great number of species and varieties among the new importations opened a broad path to the potato breeder. The difficulties were also increased. The wild potatoes did not form tubers under our conditions or yielded a useless crop, if a handful of tubers the size of hazelnuts may be called a crop. It was necessary to resort to crosses.

To the present time the majority of species, in particular the groups *Pinnatisecta* and *Bulbocastana,* failed to cross with *tuberosum* because of their taxonomic differences. Triploids, even those of *Tuberosa* such as *S. vallis mexici,* possibly are characterized by complete sterility, both male and female. There remained only the hexaploids of *S. demissum* and the numerous tetraploid group of *S. antipoviczii.* Crosses with these, especially with *demissum* were successful. But their hybrids were quite useless both as regards productivity and quality, especially in view of their long stolons. Resistance to blight was linked with none of the negative properties of the wild potato; neither with long stolons nor with late maturity. By carrying out back-crosses with *tuberosum,* repeated in subsequent generations, there may be obtained material suitable for the selection of a variety.

Recently extensive work on *demissum* has also been performed at the Institute of Plant Breeding, Münchenberg (Germany), and by the big potato breeding firm Kamecke; by Salaman and the Corstorfine Station in England, and by a number of other institutions.

The creation of varieties by means of interspecies hybridization

being a new tendency in plant breeding, it will be interesting to mention some data concerning the experience of foreign countries. E. Schmidt, a plant breeder of the firm von Kamecke makes back-crosses with *tuberosum*—up to four in number in an attempt to produce early, blight-resistant, varieties. His hybrids, as regards their economical properties, scarcely come up with the parental commercial varieties but excel them in blight resistance.

Among them were hybrids with Phytophthora-resistant tubers which is not always an attendant phenomenon of the more frequent resistance of the vine. While in F_1 the resistance to the especially virulent "Streckenthin" race of *Phytophthora* was 100 per cent in the first back-cross, this per cent fell in the following order of sequence.

	Resistance	
	Common Race Per Cent	Streckenthin Per Cent
S. demissum x *tuberosum*	100	100
S. demis x *tub.* x *tub.*	41-83	7-48
S. demis x *tub.* x *tub.* x *tub.*	44-56	7-24
The same but with the participation of susceptible varieties	5-21	0
S. dem. x *tub.* x *tub.* x *tub.* x *tub.*	0.4	0.4-22.5

S. demissum gave better results than the "wild" races of Müller, as regards resistance to the Streckenthin race, earliness and short stolons. The number of "seedlings" must be immense. Salaman of England, who has worked on the genetics and breeding of potatoes for over thirty years, until quite recently believed that work on wild potatoes, especially on *demissum*, was hopeless. In a recent letter to N. I. Vavilov he stated that his hybrids of *demissum* have been carried to the tenth generation, and that the results are full of promise. An especially important fact is that in these hybrids not only the vine but also the tubers are resistant, which is not usually observed. Salaman has evidently adopted the long course of growing many hybrid generations, not repeated back-crosses as practiced by the Soviet and German plant breeders.

Now Salaman (1934) says that "we have founded a solid basis for the creation of really resistant varieties." The ultimate success, however, he says, will depend to a considerable degree on the help that may be expected from state and industry. This once more accentuates the large scale character of the work and the necessity of big outlays for its proper development. Lapsing into a lyric mood, Salaman mentions that the path of investigation, like that of true love, is seldom smooth.

According to Rokhlina (1935) the tubers of *demissum* and *Antipoviczii* are not absolutely resistant to *Phytophthora* but differ in the degree and character of the development of the organism. An aerial mycelium and fructification may not be observed in them and even hyphae may not be found in areas of the tuber which have turned brown. *Phytophthora* shows itself only when these areas are transferred to susceptible potatoes.

Rokhlina (1935) has established that resistant species differ from susceptible varieties in the solanin content of their sprouts and vines but not of the young tubers which usually contain no solanin. The order of sequence with respect to solanin is as follows: *Antipoviczii, demissum, ajuscoense, Vallis, mexici,* Wohltman, Epicure, Granate, Kuckuck, Cobbler, Early Rose.

As regards the immunity of various species to other diseases, it may be said that some wild potatoes, such as *S. leptostigma, S. araccpapa,* perhaps some *demissum, acaule,* and *Bukasovii* are resistant to wart.* Among cultivated species about one-half of the varieties and forms of both tetraploids—*andigenum* and the Chilian *tuberosum* —may be said with certainty to be resistant. The resistance of *andigenum* to scab is evidently higher than in commercial varieties. *S. Bukasovii* is probably also resistant to scab.

Biochemical characters distinguishing the species have been established according to the content of vitamin C, glutination, nitrogen, starch, solanin, buffer index, and oxidase.

During the last two years the Biochemical Laboratory of the Institute of Plant Industry has been engaged in the extensive investigation of potato species. The mass determination of the vitamin C was possible owing to the chemical method of determination of the reducing power as outlined by Thielmans. Over four hundred tuber investigations based on the geographical principle have been conducted. It has been established that the reducing capacity, expressed in cubic centimeters of 0.001 indophenol solution calculated for 10 grams

*The data of Diehl, MacIntosh and Braun.

of substance, varies within a wide range: from 4.85 in one of the forms of *andigenum* (8543) in Khibiny to 36 in *S. antipoviczii* var. *Gaudarae* (=*S. neoantipoviczii*) in Leningrad.

Within the polymorphous species *andigenum* and *tuberosum* this range is more narrow and does not reach the above-mentioned maximum. In *tuberosum* the reduction of the vitamin C towards spring is evidently more intensive than in *andigenum*. Among the Andean cultivated species the maximum is observed in *S. Rybinii* (Bukin).

From north to south (Khibiny-Leningrad-Odessa) the content of vitamin C markedly increases.

The glutination content of the potato tubers, determined by Prokoshev, is a characteristic of the species (in mg. per 100 gr. of green tissue). Within the whole amplitude of the potato the glutination content varies within the range of from 1.31 m. the variety "Datura" to 18.05 in *S. stenotomum*. In tetraploid wild potatoes (*S. herrerae, ajuscoense* and *aracc-papa*) and in the pentaploid *S. curtilobum* the maximum to 7.22 is lower than in *tuberosum* where it is 8.81. In *andigenum* it is still higher—10.62. In diploid and triploid species the glutination content is higher than in tuberosum and often higher than in *andigenum* (above 10.62 in *mamilliferum, Rybinii, phureja, stenotomum*). The maximum glutination content in diploids is like the nitrogen content established by V. I. Nilov for *S. phureja* and *S. ajanhuiri*. The specific differences in the content of nitrogen, various carbohydrates, particularly sugar, have been established by Nilov also for other species.

These investigations are of great importance for the problem of the forage potato with a high protein content, that of the potato for the alcohol industry, and even for that of immunity.

The imperfect estimation of the alcohol potato, according to its specific gravity (balance of Reiman), must be replaced by an exact chemical estimation according to determination, of the pentosans, and verification by the biological method. In this way R. Nikolayev of the Institute of Potato Research in Moscow has been able to reveal the high value of new hybrids for the alcohol industry.

The low rate at which glucose accumulates in the tubers, according to Rozhalin (Ukrainian Potato Institute), is characteristic of varieties resistant to *Bacterium sepedonicum*.

As regards the buffer index of the tuber sap Ostanin has established that in commercial varieties this index varies within a wide range surpassing that of the Andean species. Therefore the indexes of the Andean potato lie in the higher part of the curve.

The potato species, both wild and cultivated, represents a morphological (taxonomical) unit having a definite area and being characterized by cytological, physiological, anatomical and biochemical differences,—its characters varying within a certain range.

Even species with limited areas recorded accurately for a single station represent a complex of forms which frequently are of hybrid origin.

The evolution of the species proceeded in the order of sequence of increasing chromosome numbers of the polyploid series. Diploid species are more primitive, not so much in the sense of primitive organization but in being nearer to the original forms.

To date investigators have succeeded only in obtaining new forms by interspecies hybridization. Physiologically more ancient forms are heat loving, as indicative by the higher temperature required for the germination of their seeds.

A transition from *E. Tuberosa* (tuberless) (more exactly stolonless) species of *Tuberarium* to tuber-bearing ones has not been found.

Practical Applications of Theories

Having established the potato conception in a broad sense we have extended the limits of its economically valuable properties which will have to be used for the purposes of breeding. Formerly potato breeding was purely empiric, ignoring any theory both as regards the initial material and the methods of mastering it. The new initial material ensures to plant breeding immunity to *phytophthora*, frost hardiness of the vine, a wider range of the vegetation period and the resting period of the tubers, of protein content and yellow flesh of the tuber, the content of vitamin C.

At the present time the principal method used is hybridization with subsequent selection. *S. tuberosum* or commercial varieties are indispensable partners in interspecies hybridization.

The simplest and most rapid method of obtaining prolific hybrids of high quality is to cross the commercial varieties with each other. In these crosses, heterosis plays a role. The achievements of Soviet science in this field are the varieties of the Institute of Potato Research in Moscow: Korenevskv and Lorch, and the varieties of the Institute of Plant Industry: (Vesselovskv): Epron. Komsomoletz and Kalitinetz.

Plants grown from seeds obtained from self-pollination of hybrid varieties may also serve as a material for selection. Growing of po-

tatoes from hybrid seeds on a large scale should be made use of for this purpose.

It is not certain in how far such hybridization is intraspecific as it is not impossible that *S. andigenum* has been concerned in the production of commercial varieties. Therefore much attention should be devoted to interspecific hybridization with *S. andigenum.* An important rôle in crossing with *S. andigenum* is played by the choice of the partners. To obtain high-cropping hybrids in the F_1 of *tuberosum* x *andigenum* is evidently more difficult than in back-crosses of the F_1 and especially the selection of F_2 x *tuberosum.* In F_2 and subsequent generations, in view of the omission of heterosis, the per cent of new varieties produced will possibly be lower.

In hybridization with cultivated species having a different number of chromosomes back-crossing is indispensable. In hybridization with wild species, more exactly with species in which tuber formation is poor, repeated back-crosses should be conducted.

Bud mutations may give rise to new varieties differing not only in their morphological but also in their physiological characters. T. Asseyeva has established that these mutants are of a periclinan chimercial structure.

The record beaters among commercial varieties are the extreme variants of a rather complex character (yield+quality+ecology). They give no idea of the extreme positive variants of single characters —productivity, starch content, etc.

Selection for productivity and other single not linked characters may be expedient when partners for subsequent-hybridization have to be singled out.

Interspecies hybrids may excel their parents and the standard varieties in productivity, quality, and other characters of economic importance and varieties may be produced with new properties not found in the commercial types.

Breeding for Phytophthora resistance has been most effective in the hybrids of *demissum.* The hybrids of *S. antipoviczii* produce a high yield but require further improvement.

The species chiefly used in breeding for frost hardiness are *S. curtilobum* and *S. demissum.* The other species such as *acaule* and the frost-resistant diploids have not yet been used.

In breeding for earliness attempts at utilizing *S. Rybinii sp. coll.* are being made.

As regards productivity promising results have been obtained for the hybrids of *andigenum.*

With the exception of *S. Rybinii,* the diploid and triploid potato species—even cultivated ones—to the present time have produced no promising hybrids.

The Problem of Yield and the Maximum Yields of Interspecific Hybrids

Some wild potatoes especially valuable for plant breeding (*demissum, acaule*) entirely fail under the conditions of Leningrad. Only regions with a longer vegetation period and sufficient rainfall in autumn, as in the North Caucasus and sometimes in Minsk, do these species, grown under a natural day, yield a small crop of tubers.

The behavior of nearly all other wild potatoes, with the exception of the Chilean ones, is the same. Only in exceptional years (1934) is it possible to gather a few small tubers from single plants of the wild potato, most frequently from plants belonging to the Chilean *S. leptostigma.*

The cultivated Andean potatoes, when grown in median latitudes, usually produce yields considerably lower than those of the commercial varieties. Some of them are not much better than wild potatoes.

This low productivity of all potato species with the exception of *tuberosum* raises the question as to the productivity of the interspecies hybrids having arisen from crosses with *S. tuberosum.*

The behavior of both extreme groups examined by us—wild potatoes and Andean short-day species—is as follows:

The hybrids of *demissum* (F_1) produce very different yields depending on the commercial variety used as the other parent,—according to Schmidt the yields are sometimes very high; according to Salaman, up to twenty ounces. The maximum yield obtained from the hybrids of Kovalenko was approximately twenty ounces which constitutes fifty per cent of the yield of the commercial variety concerned in the cross.

The yield of Kovalenko's triple hybrids Epicure x *demissum* x *andigenum* (*Caiceda*) is considerably higher—approximately thirty-four ounces, which constitutes seventy-five per cent yield of the commercial variety, though *andigenum,* the species concerned in the cross is a very low yielder. The yield obtained from F_2 evidently approaches these figures. The yield of Kovalenko's Epicure x *demissum* x Katahdin is ninety-five ounces. The hybrids of *Antipoviczii* bred by Sidorov sometimes produce a high yield which in back-crosses attains forty-nine ounces.

Therefore even the hopeless wild potatoes ("zero cropper" of Salaman) in back-crosses and triple hybrids may be induced to at-

tain the level of productivity of commercial varieties. As to quadruple hybrids (thrice repeated crossing with commercial varieties) they may compete with them in all respects.

The hybrids of the "prolific" species, *S. Rybinii* and *S. phureja,* with *tuberosum* have been studied but little, but even the available data show that they may not be inferior to the commercial varieties.

Thus the hybrids of *S. Rybinii* bred by Sadovnikova (Leningrad regional Potato Experiment Station) produced one hundred and four per cent of the yield of the standard variety, the hybrids of Vesselovsky considerably exceeded the parents, while in *S. phureja* hybrids the yield was one hundred and nine per cent (Sadovnikova).

Kovalenko hybrids of the frost hardy pentaploid *S. curtilobum* produced in the F_1 yield of thirty-six oz. i. e. no less than the commercial variety concerned in the cross. Triple hybrids (twice repeated crosses with *tuberosum*) considerably excelled the *tuberosum* parent, their maximum yield being fifty-five to eighty-eight ounces. About one hundred and thirty per cent of the yield of the commercial variety.

The most interesting figures are supplied by *andigenum.* In Shuntuk (N. Caucasus) when planted directly in the ground, the yield of the F_1 hybrids is thirty-five ounces whereas in Leningrad and Shuntuk, when planted from nurseries, the yield of these hybrids ranges from seventy to eighty-five ounces.

Therefore the hybrids of *andigenum* are known to excel the intervarietal hybrids of *tuberosum.* In regards to the standard varieties they considerably exceed them in yield (even in Khibiny 200%).

In all cases the yield from seedlings does not differ from the yield of the tuber reproduction, as essentially they are equal. The absolute and relative values of the yield in F_2 are nearly the same. The abovementioned figures indicate that the most important economical character—productivity—even if rather negative in the wild potatoes introduced into the crosses, may be improved by interspecies hybridization.

The starch content of some wild potatoes and in a number of cultivated Andean species is not exceeded by the best commercial varieties.

A not important achievement of the technics of breeding is the growing of seedlings. Ten to twenty years ago it was considered that potatoes grown from seeds are low yielders, the tubers being the size of nuts, and that maximum yields were obtained only when the plants were grown from tubers. However, all figures mentioned above refer to the yields obtained in the first year of life from hybrids grown from seeds. Even the extreme north was no check to the high productivity

of the seedlings, as may be seen from the figures (35 oz. to each plant) obtained for Khibiny (Murman) and the Narym Territory (Siberia). At the Vassyugan Station (Siberia) the triple hybrids of *curtilobum* yielded a larger crop than the hybrids of *andigenum*, the maximum being forty-two to forty-nine ounces. On the Parabel (Siberia) Experiment Field the yield of six hundred hybrid seedlings exceeded seven ounces to the plant, whereas seven per cent of these hybrids produced over thirty-two ounces, the maximum being sixty-five ounces. Therefore the yield of the interspecies of *andigenum* considerably excelled the yield of commercial varieties.

At the present time there are sufficient data on potato growing from seeds to show the possibilities, not only as a breeding method, but in some cases as a method for growing potatoes in extreme northern or in mountainous regions of difficult accessibility or for regions infested with virus diseases.

It is always well to bear in mind that the seeds in order to germinate require a certain temperature and degree of humidity and only careful growing of the young nursery plants will insure further successful growth. Sowing directly into the ground is not reliable and may be applied only under certain conditions.

According to the determinations made on original tubers received from Ecuador the starch content of *andigenum* is up to twenty-six to twenty-nine per cent. In the reproductions this per cent is lower, as late Andean species usually do not reach maturity under our conditions. Reliable local data on the starch content of South American potatoes are not available. There only exist general indications that a high starch content is found in var. *phina, ppitiquina, ckati* (*S. stenotomum*), *S. andigenum*: *var. imilla, ccoyn taccli, ccompes, alccai-lt armi, huamanuma, cuchillo-ppaqui, huana, S. curtilobum* (*Janckochoque pitu, luqui*), *S. juzepczukii* (*Rukki*).

Watery tubers are found in Runa, chaucha.

As regards *S. phureja* the data are contradictory. It is possible that this species having a low starch content when grown in our northern regions, may, under other conditions prove rich in starch.

In single years the hybrids of *andigenum* and *curtilobum* have a starch content ranging from twenty-five to twenty-eight per cent; the hybrids of *demissum to* twenty-six per cent (Kovalenko); the hybrids of *Antipoviczii*—to twenty-three per cent (Sidorov). In Khibiny where the limit of starch content in potatoes is low—the *andigenum* hybrids of Vesselovsky surpass this limit.

All this shows that interspecies hybridization not only reduces the

starch content but by an appropriate choice of parents, preferably varieties with a high starch content—this character may be improved.

The other qualitative tuber characters of the Andean species and wild forms—shape, depth of the eyes, taste, color—are no obstacles to obtaining hybrids of high quality. Some Andean species, more frequently wild forms and their hybrids (*Antopoviczii, demissum* and others) have tubers with small eyes, and have a shape closely resembling the ideal. In this character they greatly excel some cultivated Andean species which (like *S. ajanhuiri*) bear tubers of a "wild" aspect in the form of thin twisted rings having nothing in common with our idea of potato, or (like some *andigenum*) tubers with large knobs and prodigiously deep eyes, which would fill even the least exacting housewife with alarm.

Regarding the majority of wild forms and Andean species these tubers are of a more or less homogenous short and "round" shape.

COMPARATIVE INFLUENCE OF DIFFERENT TILLAGE PRACTICES ON THE YIELD OF THE KATAHDIN POTATO IN MAINE

P. M. Lombard

Associate Horticulturist, Bureau of Plant Industry, U. S. Department of Agriculture

Prior to the past decade, the universal conception of the value of row-crop tillage to the growing crop was that it aerated the soil, conserved moisture, increased the availability of the plant food content and suppressed weed growth. Frequent occurrence of the above statements may be found in Experiment Station bulletins and farm journals. Recent studies as for example, those conducted by Thompson and his associates (3) at the Cornell University Agricultural Experiment Station, have indicated the apparent fallacy of some of the supposed benefits from frequent tillage. Their experiments have demonstrated that the moisture conservation theory is untenable. Furthermore, the theories of the benefits derived from soil aeration and of increasing the availability of the plant food content of the soil do not seem to be confirmed by the studies referred to. Continued cultivation after the potato plants are well above the ground, in a field that has been properly prepared prior to planting and has received pre-emergence tillage to destroy weed growth, usually results in greater injury than benefit to the growing plants, because of severe root pruning, and loss of moisture from freshly tilled soil.

The experiment, upon which this paper is based, was planned to test the relative merits of a number of methods of cultivating the growing crop. It was conducted on Aroostook Farm, Presque Isle, Maine, for three years, 1931 to 1933, inclusive. Pre-emergence tillage followed by a deep cultivation as soon as the plants are up sufficiently to outline the rows, is a rather general practice in this section of Maine. This deep cultivation is made as close to the young plants as possible in order to insure loose soil for the development of the root systems of the potato plants. These practices are approved by the majority of good growers but the number and necessity of further cultivations, especially of deep cultivations, and the value of extremely high ridging have not been satisfactorily determined. Cultivation and ridging continue throughout the season until in many cases five or more treatments have been made. Five cultural treatments were compared in this experiment.

(1) Pre-emergence tillage followed by one deep cultivation and extreme ridging.

(2) No pre-emergence tillage, 2 cultivations with ordinary ridging.

(3) No pre-emergence tillage, 3 cultivations with ordinary ridging.

(4) No pre-emergence tillage, 4 cultivations with ordinary ridging.

(5) Pre-emergence tillage followed by 5 cultivations with modified ridging.

The experiment was conducted on fall plowed sod land thoroughly fitted in the spring for a good seed bed. The pre-emergence tillage, treatments 1 and 5, consisted of a light cultivation two weeks after the sets were planted. The first deep cultivation followed by the two-winged horse hoe to ridge up the soil was given when the plants were two or three inches in height. Succeeding cultivations were made at intervals of 10 days. All plants were covered with a winged horse hoe following the first deep cultivation. Extreme ridging of the plots of treatment 1 was secured by the use of a horse spade followed by the winged horse hoe.

All plots were hand-hoed to eradicate weeds following the second cultivation. Four triple-row plots of each treatment systematically replicated were grown. Each row was 1/100 acre in area. The data were then taken on a single row of each plot. The rows selected were remote from the tracks made by the tractor and sprayer wheels obviating any injury to the plants which might be caused by the spraying and cultivating operations. The average yields in bushels to each

acre for the five cultural treatments for each of the three years including both primes and culls, as well as the three-year averages, are given in table 1.

Table 1—Yields of the Katahdin potato for 5 cultural treatments. Presque Isle, Maine, 1931, 1932 and 1933

Treatment*	Year	Yield in Bushels per Acre	
		Primes	Total
1	1931	362.49	378.42
	1932	395.19	416.23
	1933	256.28	302.44
3-year average		337.9	365.6
2	1931	371.24	386.07
	1932	371.44	395.39
	1933	262.66	310.16
3-year average		335.1	364.1
3	1931	353.43	367.90
	1932	352.69	376.02
	1933	260.16	309.11
3-year average		322.0	351.0
4	1931	359.78	375.40
	1932	387.06	407.89
	1933	261.66	299.16
3-year average		336.1	360.8
5	1931	357.70	374.57
	1932	373.53	394.78
	1933	265.83	311.66
3-year average		332.3	360.3

*(1) Pre-emergence tillage followed by 1 deep cultivation and extreme ridging.
(2) No pre-emergence tillage, 2 cultivations with ordinary ridging.
(3) No pre-emergence tillage, 3 cultivations with ordinary ridging.
(4) No pre-emergence tillage, 4 cultivations with ordinary ridging.
(5) Pre-emergence tillage followed by 5 cultivations with modified ridging.

The analysis was based on the yields of primes to each acre.

The differences between the 3-year averages for any two of the treatments is rather small as shown in table 1. The value of F for treatments in table 2 shows that differences such as these might occur at random. No significant differences among these five treatments have been demonstrated, therefore, for a period of three years.

The analysis of the data was made (table 2) according to the method outlined by Fisher (1) for dividing the variance into its component parts and the probabilities of significance were determined by the use

Table 2—Analysis of variance of the yield data for 5 cultural treatments

Source	d/f	Mean Sqs.	F.
Treatment	4	474.25	
Replicates	3	1894.93	2.31 (2)
Years	2	77647.79	9.45 (1)
Treatment x years	8	407.10	
Error	42	821.54	
Total	59		

(1) Exceeds the 1 per cent value for F.
(2) Is less than the 5 per cent value for F.

of Snedecor's (2) tables for values of F. F is the ratio of the larger mean square to the smaller.

The data in table 1 show that pre-emergence tillage followed by one deep cultivation produced as high a yield as pre-emergence tillage followed by five cultivations. It is apparent then that, in this case, time and labor were wasted in excess cultivation since weed control was not a major factor. Care must be taken to control weeds at all times, however, even at the expense of a greater number of cultivations. The cultivations for weed control may be shallow so that the danger of root pruning is lessened.

Summary

The results of an experiment conducted on the Aroostook Farm, Presque Isle, Maine, for three years, 1931-'33 inclusive, to test the relative merits of five different cultural treatments in their influence on the yields of the Katahdin potato showed only slight differences. The analysis of variance showed that these differences could have been accounted for by random variability. For example, one deep cultivation after pre-emergence tillage gave yields which did not differ significantly from those obtained by pre-emergence tillage followed by five cultivations. The results might have been different if weed control had been a major factor since care must be taken to control weeds at all times. The cultivations for weed control may be shallow, however, so that the danger of root pruning is lessened.

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BREEDING FOR RESISTANCE TO COMMON SCAB IN THE POTATO

C. F. CLARK, *Associate Horticulturist;* W. P. RALEIGH, *Associate Pathologist and* F. J. STEVENSON, *Senior Geneticist, Bureau of Plant Industry, U. S. Department of Agriculture, Washington, D. C.*

The disease of the potato known as common scab, is of wide distribution, occurring in practically all the potato-producing countries. Many chemical and cultural methods of control have been tried with varying degrees of success. These results have led to attempts to secure a more efficient means of control by the use of resistant varieties. Considerable progress in this direction has been made in Europe where several varieties have been developed which possess a high degree of resistance, though none is known which is entirely immune. In this country it has been known for some time that certain varieties are less subject to scab than others, but it has not been until recent years that attempts have been made to control this disease by breeding methods.

The work on this problem by the United States Department of Agriculture, cooperating with the Maine Agricultural Experiment Station, was begun in 1930. It has included the testing of American varieties, introduced varieties, and progenies of resistant as well as susceptible parents. The first tests were conducted on land, at Presque Isle, Me., that was known to have produced scabby potatoes in previous years. The results were somewhat variable. In 1934 and 1935 lime was applied, at the rate of about one ton to the acre, before planting, to land that was known to produce some scabby potatoes in previous seasons. The reaction of a susceptible variety, Green Mountain, which was grown in each plot, as a check, showed that the scab organism was fairly uniformly distributed.

In the tests of 1934 and 1935 five hills of the variety to be tested were planted in alternate hills with Green Mountain, which is susceptible to scab. At the time of harvest, estimates were made of the percentage of infected tubers and the percentage of the area of these tubers that was covered by scab lesions. Under the conditions of the test, the product of these two percentages constitutes what is termed the scab index of the variety. Comparisons were made between the variety under test and the Green Mountain check.

A numerical expression of the amount of scab on the variety under test in terms of the percentage of that on its Green Mountain

check was obtained by dividing the scab index of the variety by that of the Green Mountain grown in the same plot.

Notes were also taken as to the type or severity of the lesions.

The scab indexes for the varieties tested in 1935, the percentage in relation to Green Mountain, and the type of lesion are given in table 1.

TABLE 1.—*Reaction of potato varieties to common scab at Presque Isle, Me.*—1935.

Variety	Scab Index of Variety	Scab Index of Green Mountain Check*	Scab in Terms of Percentage of That on Green Mt. Check	Type of Lesion†
Hindenburg	0.05	30	0.2	3
Richter's Jubel	0.05	20	0.3	3
Ackersegen	0.05	15	0.3	2
Arnica	0.1	20	0.5	2
Hindenburg X Centifolia No. 9	0.2	30	0.7	2
Dauerragis	1	20	5.0	2
Russet Rural	1	20	5.0	1
Hindenburg X Centifolia No. 15	1.4	20	7.0	2
Ekishirazu	2	20	10.0	3
Russet Burbank	3	20	15.0	2
44537	5	30	16.7	2
Goldadler	5	30	16.7	1
Golden	8	40	20.0	1
American Giant	5	20	25.0	2
Latvia Seedling	10	30	33.3	1
Mahr's Russet	8	20	40.0	2
Rural New Yorker	10	20	50.0	1
Ovalgelbe	10	20	50.0	1
No Blight	10	20	50.0	1
Beate I	20	40	50.0	1
Hellena	10	20	50.0	1
Isolda	30	50	60.0	1
45075	25	40	62.5	1
Roland I	20	30	66.7	1
Rothaut	15	20	75.0	1
Katahdin	40	40	100.0	1
Chippewa	40	40	100.0	1
Warba	15	15	100.0	1
Charles Downing	20	20	100.0	1
Columbia Russet	20	20	100.0	1
Goldappel	40	40	100.0	1
Nittany Cobbler	30	30	100.0	1
Industrie	20	20	100.0	1
White gold	30	30	100.0	1

* All tubers from the Green Mountain checks were scabby.
† Type 1 = large; 2 = intermediate; and 3 = small.

In this series of tests, which was conducted for a single season only, five of the thirty-four varieties manifested less than one per cent as much scab as Green Mountain, while in nine varieties the degree of infection was as high as in the check. Some of these varieties such as Hindenburg, Richter's Jubel and Arnica were reported, by European workers, to be scab-resistant and were brought into this country because of this resistance. This year's results at Presque Isle confirm the European reports.

A collection of South American varieties obtained in Chile by the MacMillan and Erlanson expedition was also tested in 1935. Of the ninety varieties included in this test fifty-eight exhibited as much scab as the Green Mountain. The remaining thirty-two showed varying degrees of freedom from this disease but many of the latter produced only small tubers. It seems questionable whether reliable readings are always obtained on small tubers since it is possible that they may escape infection. Further tests should bring out more information on this point.

Tests of seedling progenies were made during the period 1933 to 1935, inclusive. The first-year seedlings, from true seed, were grown without the presence of susceptible checks for comparison. Some of these single hills produced tubers with moderate to heavy scab infection. These were discarded the first year and the others were saved for the regular test the following year, in which test susceptible Green Mountain checks were used.

The material tested in 1933 consisted of a first-year seedling progeny derived from a cross between two susceptible varieties, Columbia Russet and Katahdin. White tubers were produced by all the three hundred and ninety-two seedlings and all were susceptible to scab.

In 1934 and 1935 progenies of the following parentage were tested in the scab-resistance plots: Mahr's Russets x 44537; 44537 x Katahdin; 44537 x 45075; 44537 inbred.

No. 44537, which was a parent of all the above-mentioned progenies, is a seedling with heavily russeted skin which shows some resistance to scab. It was the only russet skinned seedling in a progeny of about 2,250 obtained from a cross between two white-skinned scab susceptible varieties, Chippewa and Katahdin. Many of the seedlings of these four progenies were lacking in vigor and produced small tubers, and until further work is done on the reasons for the escape of some of the apparently resistant seedlings, the reliability of the scab data on such seedlings can be questioned. For this reason the com-

plete data for these four progenies are not included in this paper. Among the individual seedlings which produced tubers of sufficient size to give a reliable reading, however, resistance was found in varying degrees. This was true for both russet and white skin segregates of all four progenies.

Although no instances of complete immunity were evident, some were so nearly free from scab that from an economic standpoint little loss from this disease would be experienced in ordinary commercial practices. None of these seedlings is promising from a commercial standpoint but several are believed to be valuable for further breeding work and have been saved for that purpose. Several of the recent introductions, reported to be scab-resistant by foreign investigators, and found to be resistant in the 1935 scab tests at Presque Isle, as shown in table 1, may also be valuable in breeding for scab resistance, although none of them is commercially desirable for Maine conditions as compared with the Green Mountain and other well-known standard varieties.

NOTES AND BRIEF ARTICLES

REPORT OF THE WESTERN STATES CONFERENCE OF POTATO BREEDERS AND PATHOLOGISTS IN IOWA, MINNESOTA AND NORTH DAKOTA

Aug. 24-29 incl., 1936

The 1936 conference of potato breeders and pathologists was particularly successful in fulfilling the expectations of those who proposed the conference. The possibilities which they felt existed for the furthering of cooperation among the potato research workers and coordination of the work have become actualities. Every person attending this conference became better acquainted with his fellow worker, more conversant with the problems of each particular potato section, and became more capable of visualizing more clearly the national potato problem as a whole.

Through the personal contact and exchange of ideas made possible by this conference observational facts relative to plant behavior and intracacies of technique were reported which might not have appeared in print for months or years or not at all. Information of this sort is of inestimable value to the research worker and will without doubt hasten the potato improvement program.

The statistics of the meeting evidence the intense and wide-

spread interest in potato research. Representatives from thirteen states took part in the proceedings, coming from Virginia to as far west as Colorado and from Minnesota to as far south as Louisiana. The attendance totaled thirty-six composed of fourteen horticulturists, twelve plant breeders, and ten plant pathologists. Every one present heartily endorsed the resolution that a similar group should meet next year.

It was quite evident that there will be little duplication of effort in prosecuting the potato projects in the several states, for each state has problems so widely different that very little overlapping will occur. Resistance to scab is probably the only one that might be considered universal, and the nature of this problem makes duplication in different regions desirable if not necessary.

The close cooperation between the plant breeder and the plant pathologist at Minnesota is a fine example of the benefits that may accrue from coordinated effort. Much more rapid progress always takes place under such conditions. Disease is so closely associated with so many of the potato problems that the plant breeder will make little progress without the help of the pathologist.

Considerable progress has been made in developing the techniques that will provide an adequate test for disease resistance, but much remains to be done. Fundamental to this work is the greater knowledge of the nature of the many potato diseases and the determination of the variability of the causal agent; knowledge that is dependent upon exhaustive research by men in the biophysical-chemical fields in addition to the pathologist.

Recently there has been a definite increase in potato breeding. Several experiment stations are conducting new projects and other stations have expanded projects already in motion. Primarily these projects are concerned with the production of new varieties in order to regain lost markets. At some stations emphasis may be placed on scab resistance; at others on frost tolerance; at others heat resistance, etc. The potato perhaps is the most sensitive of any of our field crops to its environment. Because of this fact in will not be possible to find one variety that will satisfy all conditions even in one state.

Wholly aside from the production of new varieties by clonal selection or by selection following hybridization or by the not infrequent mutation or chimera, the potato breeder is concerned in building germ plasm. The pioneer work in developing pollen producers has been conducted by Wm. Stuart, C. F. Clark, F. A. Krantz, and oth-

ers. The variety Katahdin and other strains producing an abundance of viable pollen have made possible a much broader breeding program. At present the breeders are endeavoring to incorporate vigor and one or more other desirable characters in the fertile inbred lines, anticipating greater improvement when these lines are recombined. In addition, when these lines become available it will be possible to hybridize certain plants for particular purposes, predictable in advance.

It is hoped that the Division of Fruit and Vegetable Crops and Diseases through the efforts of Dr. F. J. Stevenson will act as a clearing house for the breeders of the country. As the inbred lines and testers are developed by the several breeders, information concerning the lines and seed and tuber stocks will be available through Dr. Stevenson. In this way much lost motion may be prevented and much greater progress accomplished in the industry as a whole.

It was the concensus of opinion of those present that these conferences should be held frequently. It was suggested that the next one might be in the eastern section of the country presumably in 1937.

CONFERENCE OF POTATO WORKERS IN THE HIGH PLAINS AREAS

R. W. Goss

University of Nebraska, Lincoln, Nebraska

On August 18 a conference of potato workers was held at Scottsbluff, Nebraska. Representatives from the states of Colorado, Wyoming, Nebraska, and the U. S. Department of Agriculture were invited for a discussion of the potato problems common to the high plains area of the three states. Workers in the fields of horticulture, plant pathology, and entomology were present, together with certification officials and representatives of the Extension Service and the U. S. D. A. Division of Western Irrigation Agriculture.

The morning was spent in the inspection of the twenty-five-year-old rotation plots of the Scotts Bluff Field Station and experimental plots dealing with psyllid control, effect of seed piece exposure on stand, date of planting and yield, tests with new varieties, new seedlings, hybrids, and foreign introductions, and experiments on irrigation methods.

The afternoon was devoted to a discussion of experimental work in progress and to the disease and insect problems prevalent in the region. The National Potato Improvement Program was discussed in detail from both the pathological and horticultural aspects.

The free exchange of experiences, opinions and unpublished experimental evidence was considered to have been very helpful and investigators voted to make a field meeting of a similar nature an annual affair. Professor Metzger of Colorado was elected to have charge of the arrangements for a two-day meeting next year, which meeting is to be held in Colorado. Workers from states having similar problems are cordially invited to attend these open field days and discussions.

SECTIONAL NOTES

CONNECTICUT

Heavy showers during the latter half of August assured sufficient moisture for potatoes the remainder of the season. The well-sprayed fields of the commercial growers were, for the most part, green in early September and, therefore, in a condition to produce a large yield. However, the vines in poorly sprayed fields were largely dead before September 1 and, undoubtedly, yields will be curtailed in such cases. There may be some loss of tubers on fields where vines stopped growing during the dry period and then renewed growth with the occurrence of rains. However, on the whole, the crop should be about twenty per cent above that of 1935.

Prices now range from $1.15 to $1.35 to the bushel, wholesale. (Sept. 14).—B. A. Brown.

IDAHO

It is still a bit early to prognosticate Idaho's potato crop. For the most part, 1936 has been a normal season. Excessively high temperatures during July and early August favored attacks of fusarium in fields where potatoes followed potatoes or sugar beets. Comparatively little of this trouble has been reported from fields where potatoes were planted after alfalfa or clover.

Leafhoppers are causing damage in some districts, but not to the extent of last year. For the most part, the stand of potatoes over the state is not quite normal in that temperatures were high in districts where the crop was planted late. All these factors will of course, tend to reduce yield.

From the observations we have made, and judging from reports from growers in various districts, we rather expect a high percentage of No. 2 stock. This is probably the result of the excessive and sudden changes in temperature that occurred after the tubers set. Many

potatoes are irregular in form, some are pointed, and others are knobby. So far, no frost injury of importance has been reported, and the total yield of the state will depend quite largely on the length of the growing season. Many growers have complained that the tuber set is rather late and irregular, so that if frost should occur at this time the plants would not produce normal yields. However, probabilities indicate we will still have from one to three weeks of favorable growing weather in most of the potato districts, which should enable the larger part of the fields to produce maximum-sized tubers.

We are advising our growers to try all measures, fair or foul, to secure as large a yield as possible, even at the expense of quality. This is in opposition to our usual policy, but with the present outlook, we feel that No. 2 potatoes will bring a fair price, and at present the important factor is to obtain the potatoes.

We are also making a special effort to induce our growers to exercise particular care in harvesting and storing to prevent the usual losses that follow carelessness during harvesting operations. (Sept. 15).—E. R. Bennett.

INDIANA

There has been little change in the situation in Indiana during the last month. The northern part of the state, however, received some beneficial rains and cooler weather, whereas central and southern Indiana suffered considerably from a second hot and dry spell which is still in effect. From our observations it appears that we will need a considerable quantity of potatoes in Indiana to care for our needs during the coming season. (Sept. 10).—W. B. Ward.

MASSACHUSETTS

Massachusetts is harvesting a good crop of potatoes this year. The Cobblers have been dug with satisfactory yields and good quality. Green Mountains are now being harvested. Yields are running satisfactorily and most commercial crops are slightly better than normal and much better than last year. The quality is also good. A few cases of late blight rot are evident but damage from this is not yet very widespread.

Prices have maintained a satisfactory level and quotations at present are approximately $1.80 a hundred. In most cases growers are shipping moderate amounts to market, amounts sufficient to maintain any retail demands and to clean up production costs. The balance of the crop may be held until later for a possible advance in price. (Sept. 14).—Ralph W. Donaldson.

NEBRASKA

We report with reluctance on the condition of the Nebraska crop. If you have followed the previous reports, you will think that we are pessimists in every sense of the word, but the fact remains that western Nebraska has gone through one of the most disastrous seasons ever experienced. The season of 1934 set the pace, but 1936 is not going to take a back seat from the standpoint of lack of rainfall, heat, and final destruction of crops.

There has been no relief from the standpoint of rainfall, and plants that appeared reasonably good a month ago, have burned considerably. In a very few instances has there been any improvement on the dry land areas. The irrigated crop, of course, has grown steadily, and although the water supply is short, it has been ample to this time, and the crop has progressed rapidly. The yields will not be equivalent to those harvested in 1935, but they will be reasonably large, and probably will be about normal.

The dry land grower now hopes for his seed. Many of them know definitely that that is out of the question, because a great many fields have turned out to be just good summer fallow instead of potato fields. There are, of course, a few exceptions, where the fields have improved during the last month. The difference will apply to probably less than ten per cent of the entire crop. Our estimate at this time is for approximately ten per cent of a normal yield throughout the dry land territories.

Most buyers are reluctant to take on futures, because of the precarious condition of the crop. Growers have high prices in mind, ranging from $3.00 to $4.00 per cwt. A small acreage is now being dug, and is selling for approximately $1.75 f.o.b. to the grower.

The Sales organization of the Nebraska Certified Potato Growers refuses to quote Certified seed for winter shipment, until the harvesting is actually under way. As a result of this, no prices have been established for the seed deal.

Growers are now making a desperate effort to protect themselves for another season, so that they will not be entirely out of the potato business. Unless something very unusual occurs, the Certified and commercial acreage on dry land will be appreciably reduced next season. It is the opinion of many who are interested in potato seed and table stock that the industry will be severely crippled next year. (Sept. 10).—MARX KOEHNKE.

NEW JERSEY

Recent reports indicate that approximately 85 to 90 per cent of the New Jersey crop has been harvested and shipped. This is a much larger proportion than is usually shipped by this date. Last year, for example, less than half the crop was shipped by Labor Day. At the present time the growers are receiving $1.70 per hundred pounds for sacked, graded stock. Since those who have potatoes are not anxious to sell, the movement from now on will be slow. Several of the larger dealers report that this is one of the best seasons the New Jersey grower has experienced for a number of years.

The first field inspection is now being made of the late-planted potatoes entered for certification. A total of 475 acres was entered for certification, including the following varieties. Irish Cobbler, 377¼; Red Skin, 81; Green Mountain, 2½; Chippewa, 4; Warba, 3; Katahdin, 3½, and Superba, 3 acres. (Sept. 16).—WM. H. MARTIN.

PENNSYLVANIA

Certified seed fields in the mountainous counties have made excellent growth during the past month. The majority of our seed fields are located in the mountainous sections of the state although a few fields are being certified at the lower altitudes. The lower lying fields were somewhat injured by the intense heat during the summer and are not expected to yield so well as the fields located in the mountainous areas.

This year the rejection of fields will probably be the lowest on record. We usually reject approximately thirty-three per cent of the acreage entered for certification. Our late-planted fields gave good stands but made very little growth until the latter part of August. The intense heat undoubtedly masked many of the diseases, that under normal conditions, would have shown up quite prominently and resulted in more rejections. Our experience this year parallels our work during the hot and dry summer of 1934. Our rejections in that year were much lower than usual.

If killing frosts do not appear until the latter part of September we may predict a heavy crop of certified seed, as most of our certified fields are still green. Our cobbler yield will be short even though we had a considerable increase in the acreage of this variety as compared with those certified last year. The cobbler fields were considerably injured during the dry hot weather of July and early August.

Although the final field inspection has not been completed, we expect to have approximately 850 acres certified in Pennsylvania this year. The approximate acreages of the various varieties entered for certification are as follows: Russets, 460; Cobblers, 193; W. Rurals, 150; Bliss Triumph, 37; and Katahdin, 10.

With normal conditions existing from the present time to the end of the digging season we should have a crop of approximately 200,000 bushels of certified seed potatoes. (Sept. 14).—K. W. LAUER.

RHODE ISLAND

The Cobblers have been harvested and the Green Mountains are being dug. The early crop on the average was generally better than expected. One field of more than one hundred acres averaged three hundred and sixty bushels. During midseason the yield was considerably reduced on the lighter soils because of the drought.

The late crop should produce some very fine yields. A large percentage of this crop will probably be stored on the farms.

The price is still approximately $2.00 per cwt. (Sept. 8).—T. E. ODLAND.

VERMONT

Entries for seed certification in Vermont totaled slightly under five hundred and fifty acres. Final inspection figures are not complete, but approximately five hundred acres will be certified. About forty additional acres were represented in the central test plot, but these were not officially entered because of bad showing or other causes. About seventy-five per cent of the acreage to be certified are Green Mountains; twenty per cent Irish Cobblers; and five per cent other varieties including Katahdin, Chippewa, Spaulding and Early Rose. The one small entry of the last-named is progeny of the Canadian strain developed under supervision of the Dominion Certification Service at Nova Scotia.

Many of the fields entered for certification will apparently yield well. There was a good set, and proper fertilization and spraying have maintained fairly vigorous growth.

The small commercial fields which receive little attention will produce poorly. Many have died early because of the hot weather in mid-season, early blight and insect injury. Since such fields compose a large part of Vermont's total acreage, a light crop may be expected. Very little late blight has been observed to date.

The annual summer meeting of the Vermont Certified Seed Potato Growers' Association of Randolph Center, August 11, with Dr. W. H. Martin of New Jersey as principal speaker surpassed its usual good form in interest.

No sales of seed have been reported and there has been little trade reported in table stock. A few that were sold locally during the latter part of August brought as high as $2.00 per bushel but later sales have been made at $1.00 per bushel. (Sept. 10).—H. L. BAILEY.

WASHINGTON

The growing conditions in Washington have, in general, been very good during the present season. The general rain which prevailed during the first week in September assures a large yield from the late-planted fields.

Early varieties have been harvested and marketed. The mid-season varieties, mostly White Rose, are practically all marketed. A considerable amount of the late varieties has also been harvested. A larger percentage of our total potato crop has been sold at the present date than has occurred at this time for ten years or even for a longer period. Approximately one-third of our crop has been marketed.

The total seed potato acreage entered for certification is slightly smaller than last year but a larger acreage will undubtedly meet the requirements this year. Weather conditions have been more favorable which will naturally result in increased production to the acre and total production. (Sept. 11).—CHAS. D. GAINES.

WISCONSIN

The abrupt change from extremes of heat and drought to favorable conditions during the past two weeks continues to show a steady gain in crop prospects in Wisconsin. The degree of recovery of course varies widely in the various potato belts of the state. The extremely high soil temperatures during July and August did most severe damage on the light sandy soils of the state.

The Wisconsin Potato Tour, August 3-6 was confined largely to the heavy producing sections in the Langlade, Oneida County area. Several irrigation projects had been started in this section. In the main, pipe lines were laid from lakes or streams and the water pumped to fields through an overhead revolving nozzle system.

In the case of two projects in the Antigo area, two large reservoirs of water were made available by excavating a pit about 100 feet square and approximately 15 feet deep.

In this case water was available at about a ten-foot depth, and an abundant supply was made available under constant pumping operations at the rate of six hundred gallons each minute. Growers in Wisconsin are watching these operations with interest. The evidence points to profitable returns in 1936. Preparations were made hurriedly under emergency conditions this year, and there will be considerable equipment available for continued applications of watering during dry periods in future seasons.

Comparatively speaking, the yield has been very good in Wisconsin on several peat soil sections, where the early varieties are grown mainly for the early fall trade. During the latter part of August the plants on these soils, apparently recovered, and some very creditable yields of Irish Cobbler and Triumph are being harvested at this date. (Sept. 10).—J. G. MILWARD.

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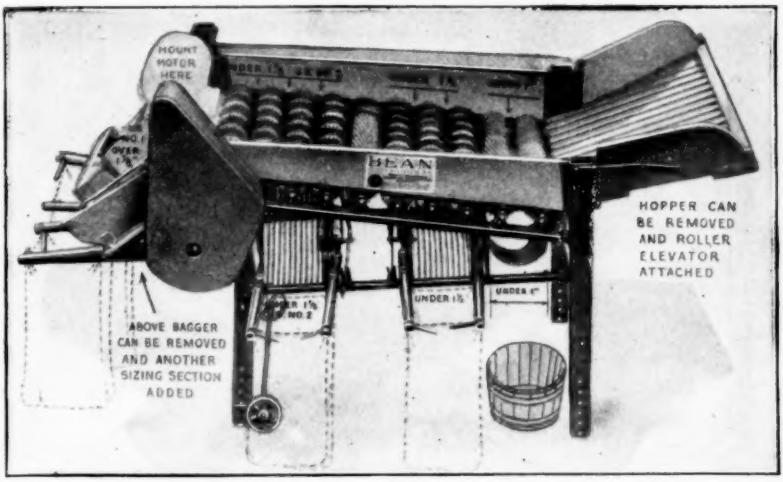
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PLANNING FOR 1937

So much has been said about planning for the potato industry in recent years and so little of a definite nature accomplished, that the average potato grower is likely to give scant consideration to any discussion of this question.

It is difficult also for the grower to give much thought to planning when he has experienced a good year. When all bills are paid and a balance is on deposit, the future does not look so gloomy as in a year when production costs are not realized. Planning usually results from crop failures rather than from successful crops. We have little desire to do much in the way of improvement when the situation appears favorable.

We must not lose sight of the fact, however, that this year's prices came not entirely as the result of our own good management but rather because of conditions over which we had no control. The acreage planted in the United States, with normal yields, would have resulted in prices not far different from those of the past two years. This would have been followed by the ruin of many of our potato growers.

It appears to be difficult to accomplish much in the way of planning for the industry as a whole. The individual grower must however, seriously consider his plans for next year. A year of good prices is frequently followed by increased plantings. Difficulties will be experienced if a majority of the potato growers follow this practice. The grower should plant only the acreage he can take care of adequately. By this means he can keep his production costs down and will be prepared for low prices if they should prevail. The potato grower should also give serious consideration to soil- conserving crops and soil-building practices. If each grower would adopt a sound program, the industry should hold the gain made this past season.